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PV solar system feasibility study

Moh'd Sami S. Ashhab [a,*], Hazem Kaylani [b,1], Abdallah Abdallah [b,1]

[a] Department of Mechanical Engineering, The Hashemite University, Zarqa 13115, Jordan
[b] Department of Industrial Engineering, German Jordanian University, Amman 11180, Jordan

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ABSTRACT

This research studies the feasibility of PV solar systems and aims at developing the theory and application of a hybrid system that utilizes PV solar system and another supporting source of energy to provide affordable heating and air conditioning. Relevant research topics are reviewed and some of them are discussed in details. Solar heating and air conditioning research and technology exist in many developed countries. To date, the used solar energy has been proved to be inefficient. Solar energy is an abundant source of energy in Jordan and the Middle East; with increasing prices of oil this source is becoming more attractive alternative. A good candidate for the other system is absorption. The overall system is designed such that it utilizes solar energy as a main source. When the solar energy becomes insufficient, electricity or diesel source kicks in. A prototype of the PV solar system that operates an air conditioning unit is built and proper measurements are collected through a data logging system. The measured data are plotted and discussed, and conclusions regarding the system performance are extracted.

1. Introduction

Solar heating and air conditioning research and technology exist in many developed countries. To date, the used solar energy has been proved to be inefficient. Solar energy is an abundant source of energy in Jordan and the Middle East; with increasing prices of oil this source is becoming more attractive alternative. This research aims at developing the theory and application of a hybrid system that utilizes solar system and another supporting source of energy to provide affordable heating and air conditioning. It also represents an extension of [1]. The system will be designed such that it utilizes solar energy as a main source. When the solar energy becomes insufficient, electricity or diesel source kicks in.

Most of the energy demands in Jordan and the Middle East are currently in the form of petroleum products that are expensive. This makes the development of renewable energy systems very attractive. For Jordan, the share of renewable energy in the total energy consumption was around 1% in year 2004 and is expected to rise up to 15% in year 2010 [2]. Solar energy is very promising in Jordan due to its availability for most of the time throughout the year and has been used for food canning, paper production, air-conditioning and sterilization [3].

The objective of this research is to create a new solar system that can be built and marketed commercially at low costs. The project will ensure results by building actual prototypes and creating proper business case for commercial use in local markets. In addition, relevant data will be collected for the prototype. The data will be utilized to obtain a model for solar systems performance estimation and improvement. A follow up benefit will be to provide the poor and low income families the ability to afford some luxuries in life such as heating and air-conditioning.

To date, people enjoy heating and air conditioning in houses and offices by utilizing current available sources of energy such as electrical energy or an energy derived from oil. This caused two separate issues; power grids in many major cities and states are overwhelmed by the high demand on energy caused by heating and air conditioning, and the fact that the current sources are expensive, makes it difficult for the poor to afford such luxuries.

Using solar energy for the purposes of heating and air conditioning has seen some visibility. The main issue with using solar energy is that it has not yet been made efficient enough to be a viable source for energy. Finding a viable design that utilizes solar energy as the main source of energy will indeed have immense benefits in the middle east countries, especially the none oil countries, since these countries will not have to use as much oil or electricity. Such savings will help individuals to afford heating and air conditioning in addition to allowing countries to keep more oil and electricity power to be used for other purposes.

One potential concept of the design to possibly be used will utilize the basic principles of "Design for Six Sigma" in order to create an efficient design of a system that will allow for two sources of energy to be used; solar energy and electricity (or oil). This system will mainly utilize solar energy and partially electricity. The system

* Corresponding author. Tel.: +962 5 390 3333; fax: +962 5 382 6348.
E-mail addresses: sami@hu.edu.jo (Moh'd Sami S. Ashhab), hazem.alkaylani@gju.edu.jo (H. Kaylani), abdallah.abdallah@gju.edu.jo (A. Abdallah).
[1] Fax: +962 6 534 1573.

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will be fully designed with all logical controls and electrical systems needed to make it ready for use.

Solar energy has been used for many purposes thus far; water distillation, electricity generation through voltaic cells, water heating, and domestic heating and air conditioning. Some of these applications are widely used such as water heating, but for the most part, solar energy is not used due to the fact no one could produce efficient and consistent solar energy.

Another issue in using solar energy has been the fact that such energy is produced by using large solar collectors that needs large space. Such collectors could also be expensive to purchase or build. Solar energy is free energy otherwise. To date, research concentrated on developing new means for collecting solar energy. New solar collector designs have been used in the last few years. Such advances have not yet made solar energy sufficient to be used as a sole source of energy for just about any application.

Design for Six Sigma (DFSS) is a design methodology that utilizes innovative techniques to design and validate new products. DFSS methodology stresses the usage of innovative techniques such as Theory for Inventive Problem Solving Technique (TRIZ) and Robust Design to design new systems that are efficient and reliable. DFSS and TRIZ have been used widely in the western hemisphere to provide process improvements and to create new innovative designs. While these methods have not seen massive use in the area of solar system design, they have been used in a wide range of product and process design. The success of these methods is proven every day, and this allowed the team to believe such sound methods can be linked successfully to create new hybrid solar energy system.

In this research it is intended to link three areas of research to maximize the productivity and efficiency of the system: Solar energy basics, DFSS, and logic (control) systems.

2. Relevant research review

Jordan imports most of its energy demands in the form of petroleum products. In order to meet the country's future increasing energy demands some of the conventional thermal energy systems should be replaced by renewable energy systems. Thus, the development of renewable energy systems is very attractive. The share of renewable energy in the total energy consumption was around 1% in year 2004 and is expected to rise up to 15% in year 2010 [2]. Solar energy is very promising in Jordan for its use in food canning, paper production, air-conditioning and sterilization [3]. Water heating accounts for about 20% of the total energy consumption of residential buildings, and about 7% of business buildings [4]. Solar heated water by flat plate collectors is considered one of the commonly used, reliable and maintenance free sources of domestic hot water in most of the countries [5]. Research in the area of solar energy has been very active in Jordan due to its extreme importance.

An experimental study of the performance of a thermal photovoltaic solar integrated system which was designed and assembled in Jordan has been carried out by Hammad [5]. The solar system consists of a solar trainer which contains a photovoltaic panel, a DC centrifugal pump, flat plate collectors, storage tank, a flowmeter for measuring the water mass flow rate, pipes, pyranometer for measuring the solar intensity, thermocouples for measuring various system temperatures and wind speed meter. Further analysis of the system with the aid of artificial neural networks (ANN's) has been performed in [6,7], where the author utilized the ANN model of the solar system to find the optimum operating condition that will produce maximum system efficiencies. Historical input–output system data that was collected experimentally is used to train an ANN that predicts the collector, PV module, pump and total efficiencies. The model predicts the efficiencies well and thus can be utilized to find the operating conditions of the system that will produce the maximum efficiencies. This is done using the complex method constrained optimization [8] applied to the solar system ANN model. The optimum operating conditions will be very hard to obtain by just looking at the available historical input–output data. An ANN based inverse controller is designed to achieve the optimum efficiencies which is difficult to design by just looking at the historical data. The study and procedure can be carried out for other solar systems towards achieving their best performance. Applications of neural networks are numerous and include many various fields. ANN's have been used for forecasting photovoltaic solar integrated system efficiencies [6,7], and solar energy [9].

Solar heating systems with seasonal energy storage have attracted an increasing attention over the past decades. A solar heat pump heating system with seasonal latent heat thermal storage is described in [10]. In the same paper a simplified mathematical model for a heat thermal storage system was developed. Using the model developed, the operational performances of the system which provided space heating to a villa building have been investigated by simulation. In [11] the authors explored the possibility to perform heating and air-conditioning of state of the art building located near Paris in France. A study of the performance of a solar heating system with seasonal storage is evaluated using finite element method in [12]. Experiments on solar heating and cooling systems were conducted in [13,14].

"Theory of Inventive Problem Solving Techniques" (TRIZ) and "Design For Six Sigma" (DFSS) are proven methods to design and develop near perfect products. While both tools are used extensively to design new and evolved systems, there has not been a documented published research linking these methods to designing solar energy systems that can be used for purposes such as heating and air conditioning.

3. Hybrid solar systems review

In this research we conduct a feasibility study of a system which belongs to hybrid solar systems family. Hybrid solar systems have gained a lot of attention recently due to their need and great importance in the green energy field. Due to the fact that the relationship between various relevant parameters in those systems is complex a lot of experimentation and feasibility studies have to be conducted in order to achieve reliable results about performance and efficiency. Towards this end, a review is made here of some of the feasibility studies of previous hybrid solar systems with special attention to a photovoltaic solar integrated system in Jordan.

A series of initial experiments to demonstrate the feasibility of hybrid photocatalytic–photovoltaic systems for simultaneous water purification and electricity generation have been conducted in [15] where the findings indicated both technologies can work simultaneously, producing drinking water and generating electricity to feed a pump, which establishes the path for a complete autonomous system. In [16] the technical and economic feasibility study of an innovative wind–solar hybrid renewable energy generation system with rainwater collection feature for electrical energy generation was presented. The power generated would supply part of the energy requirements of the high-rise building where the system was installed. The system integrated and optimized several green technologies; including urban wind turbine, solar cell module and rain water collector. The authors of [17] proposed a hybrid solar cooking system where the solar energy is brought to the kitchen. The energy source is a combination of the solar thermal energy and the Liquefied Petroleum Gas (LPG) that is in common use in kitchens. The modeled system was simulated and the results are validated experimentally. In [18] a new techniques system was proposed in Thailand of sufficiency energy using solar cell created